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TITLE OF THE INVENTION

FIRE AND CORROSION RESISTANT THERMALLY STABLE ELECTRODES AND  
BATTERIES AND METHOD FOR MANUFACTURING SAME

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5 FIRE AND CORROSION RESISTANT THERMALLY STABLE ELECTRODES AND  
BATTERIES AND METHOD FOR MANUFACTURING SAME

FIELD OF THE INVENTION

10 The disclosed device relates to electrochemical devices for  
storing electrical energy. More particularly it relates to the  
formation of the battery electrodes by adhering the actives  
forming the electrode directly to the current collectors which  
are formed of a layer of conductive polymer film or tape.

15 BACKGROUND OF THE INVENTION

20 Conventional electrochemical devices such as batteries, are  
used widely in the world as a source of portable electrical power  
from direct current. Such battery devices provide the electrical  
power for everything from watches to automobiles and as a  
consequence great value is placed on the energy density or  
25 electrical storage capacity of these devices and their continued  
ability to provide an adequate supply of electrical current to  
the communicating electrical device. Currently the lithium ion  
battery is a preferred battery configuration due to its inherent  
ability to store and discharge a large volume of electrical power  
in relation to its volume and weight.

5           The conventional construction of lithium ion batteries  
features a positive and a negative electrode formed of active  
material on a metal substrate. The electrodes are then encased  
in a cell can or casing whereupon both electrodes release and  
absorb lithium ions during discharge and charge of the battery  
10 depending on the direction of current flow. During discharge of  
the battery, the active material in the negative electrode  
releases lithium ions which are absorbed by the positive  
electrode and this process is reversed during charging of the  
battery whereby the positive electrode releases lithium ions to  
be reabsorbed by the negative electrode.

Continued function of batteries requires that a separator be  
placed between the positive electrode preventing it from direct  
contact with the negative electrode. Conventional lithium ion  
batteries achieve this separation using a separator made from a  
porous membrane made from a suitable dielectric material to  
20 maintain the desired degree of separation of both electrodes and  
allow passage of the electrolyte therebetween during the ion  
exchange when used.

An existing problem with the manufacture of conventional  
25 lithium ion electrodes arises from metal shards that are produced  
during the slitting process involved in forming the electrodes to

5 the proper dimensions for encasement. These shards pose a  
constant danger of damage to the separator and potential shorts  
between the two electrodes resulting therefrom.

Both electrodes also communicate with a current collector  
which communicates the electrical current generated during  
10 discharge of the electrodes of the battery and permits the  
electrodes to communicate with an external power source which can  
be used to recharge the battery. Such current collectors further  
communicate battery developed electrical current to the external  
device which uses the battery as source of electrical power.

15 Conventional current collectors are frequently manufactured from  
stainless steel, iron and nickel alloys, aluminum, copper, and  
similar materials that provide good electrical communication  
between the load drawing power external to the battery casing and  
the electrode housed internally.

20 As a medium to move the ions between the electrodes an  
electrolyte is used. A conventional electrolyte in a lithium ion  
battery contains lithium ions which move between the electrodes  
during charging and discharging. Such electrolyte provides the  
means of transport of the lithium ions through the porous  
25 separator which separates the two electrodes formed of active  
material. Typical electrolytes will not function above 150° C.

5           The constant flow of ions in the proximity of the current collector during discharge and charging of the battery has a high potential to cause corrosion of the current collector itself and the contact points with the electrode thereby degrading the communication of electrical current from the adjacent active material of the electrode. Such corrosion is caused by a number of factors in a lithium ion battery including but not limited to low corrosion resistance of the current collector, high temperatures caused by charging and discharging, the inherent nature of lithium being highly reactive, and other interrelating factors. Conventionally, aluminum and copper are especially susceptible to corrosion from the salts in the electrolytes in a lithium ion battery. Further, there is also a susceptibility to corrosion of current collectors of conventional batteries which can be attributed to inhomogeneous current flow through the current collector itself once it has become corroded and thereby come into uneven contact with the adjacent electrode.

          An additional problem with conventionally manufactured lithium ion batteries is the requirement that once manufactured, they must be charged. Typically to prevent corrosion of the copper current collector, batteries must be charged to at least 10% of capacity so that they may be stored and shipped to

5 customers. This is an expensive and time-consuming step in  
manufacture.

In dealing with lithium ion batteries there is the further  
vexing problem of combustion of the highly reactive materials  
forming the electrodes. The material forming the electrodes has  
10 a propensity to catch fire if the battery is overcharged or  
charged at the wrong voltage or overheated by an internal or  
external short.

As can be discerned, it is imperative that corrosion between  
the termination collectors adjacent to communicating active  
15 material forming the electrodes be kept to a minimum to avoid  
loss of efficiency of the battery. Such corrosion also risks the  
total failure of the battery should contact be lost between the  
termination collector such as the current collector or the  
battery case, and its communicating electrode. It is further  
20 highly desirable to eliminate the potential of shards and debris  
from the manufacturing process causing short circuits between the  
electrodes by circumventing the separator. Finally the reduction  
of the potential of fire during overcharge or short circuits  
internally or externally is highly desirable.

25 One solution attempted to prevent such fire hazards from  
short circuits has been the use of a non flammable electrolyte in

5 the battery. Such a teaching of the use of a flame retardant electrolyte is found in US Patent 6040091 (Hiroaki) and US Patent 5714277 (Kawakami) as well as other patents. However placement of a flame retardant in the electrolyte as taught by these and other patents inherently complicates the chemistry of the battery since it renders the cell sensitive to voltage and the cell can decompose, as well as limiting the stability of the electrolyte itself.

U.S. Patent No. 5,547,782 (Dasgupta) attempts to solve the problem of corrosion of the current collector by using an electrically conductive ceramic layer or electrically conductive polymer in a stacked relationship between the electrodes and the metal cover and case forming the battery container. However, Dasgupta also teaches the requirement that the polymer layer must be continuous and non-porous to prevent the severe corrosion caused by contact of the electrodes with the metal surfaces protected. This makes Dasgupta more expensive and not easily manufactured and fails to address the problem of shards and debris contaminating the electrodes and the need to pre-charge the battery before shipment to avoid corrosion.

U.S. Patent No. 5,187,033 (Koshiha) teaches a lithium secondary battery using a porous film separator and a gold plated

5 stainless steel current collector and uniquely formed electrodes.  
However Koshiha fails to address the issue of shards piercing the  
separator and the potential for corrosion with the metal current  
collector and the metal powder used therein, the fire hazard, and  
would still generally require a charging of the battery before  
10 storage and shipment.

There is a pressing need as such, for a method and  
components for use in battery construction which will provide for  
maximum communication of current from the electrode to the  
adjacent termination component and concurrently provide maximum  
15 resistance to the corrosion threatening that communication  
between the electrode and the termination component. Such a  
method and components used therein to form the resulting battery,  
should provide maximum resistance to such corrosion by maximizing  
the contact of the termination component with the adjacent  
20 electrode and should be easy to include in battery construction  
and be inexpensive. Further, a battery so formed, should  
minimize or eliminate the hazards of metallic shards causing  
short circuits and minimize the potential from fire in the  
battery. Additionally, such a battery should maintain thermal  
25 stability at high temperatures and should not be required to be  
pre-charged before shipment.

## 5 SUMMARY OF THE INVENTION

The above problems, and others are overcome by the herein disclosed components and method of construction of an improved Lithium and lithium ion battery. The device features current collectors formed of non-metallic substrates of a polymer or carbon tape layer on which the actives forming the electrode are laminated or coated directly to one or both sides thereof to form a unitary structure featuring the current collector on one layer and the actives on another. Such a construction tends to minimize corrosion while concurrently maximizing conductivity with the electrode and alleviates the requirement of a non-porous layer between the electrodes and the metal case and cover. As corrosion potential is greatly reduced by this construction of the internal components, the need to pre-charge the battery before storage and shipment is eliminated. Additional utility is provided through the optional inclusion of flame retardant additives in the tape layer and/or the electrode actives. An additional benefit afforded is the elimination of the requirement to charge such batteries immediately upon manufacture and before shipment, storage, or sale.

25 The conducting tape may be a conducting particle-dispersed plastic or a plastic dispersed carbon tape. For the conducting

5 particle-dispersed plastic tape, the plastic is continuous phase  
and provides the mechanical strength required by the typical  
continuous coating equipment used to adhere the actives thereon.  
Dispersed conducting particles in the tape provide a conducting  
10 path for electrical current communicated from the active layer  
formed on the tape. In the case of plastic dispersed carbon  
tape, the carbon is the continuous phase and provides not only  
the required strength during manufacture but also the conducting  
path for the electrical current. Metallic powders such as  
15 Aluminum or Copper may be added to either tape matrix to reduce  
resistance therein. The electrode formed is thermally stable at  
high temperatures of at least 240 degrees centigrade which is an  
important feature since the battery will endure the rigors of  
solder reflow where the battery is soldered to the circuit board  
by dipping it in molten solder and affixing directly to the  
20 board. Additionally, as earlier noted, flame retardants may be  
added to the tape matrix to thereby inhibit fire in the battery.

Since the collector is a polymer or carbon film, the current  
collector can be compressed during manufacture without damaging  
the finished battery and providing an outward biasing from inside  
25 the battery case to maintain contact pressure between the current  
collector and the exterior electrical contact.

5           Accordingly, it is the object of this invention claimed  
herein to provide an electrode design and resulting battery that  
is safer and more corrosion resistant and fire resistant than  
conventionally available batteries.

10           It is another object of this invention to improve the  
intrinsic safety of a battery electrode by reducing the potential  
for fire in the cell through the use of fire retardant materials  
allowed by the unique component structure.

15           It is still another object of this invention to supply non  
metallic substrate electrode capable of withstanding the  
mechanical and thermal stresses of high volume production.

20           It is a still further object of this invention to provide a  
battery cell current conductor that is non metallic and provides  
a better connection to the adjacent electrodes.

25           It is an additional object of this invention to provide a  
lithium ion battery cell which once manufactured, does not  
require pre charging before shipment and sale or can be charged  
to a charge between 0 and 10 percent of capacity and not suffer  
degradation or corrosion during storage.

          A still further object of this invention is the elimination  
for the need for non-porous layers to be stacked between battery  
cell walls and the electrodes in lithium ion batteries.

5           Additionally, it is an object of this invention to remove  
the need for Copper and Aluminum current collectors and thereby  
provide for the use of high temperature electrolytes in a lithium  
ion which would attack the conventional metallic current  
collectors.

10           Further objectives of this invention will be brought out in  
the following part of the specification, wherein detailed  
description is for the purpose of fully disclosing the invention  
without placing limitations thereon.

15           **BRIEF DESCRIPTION OF THE DRAWING FIGURES**

The accompanying drawings which are incorporated in and form  
a part of this specification illustrate embodiments of the  
disclosed processing system and together with the description,  
serve to explain the principles of the invention.

20           Figure 1 depicts a side cut away view of a preferred  
embodiment of the disclosed device featuring a foil current  
collector coated on one side with active material.

Figure 2 depicts a side cut away view of an additional  
preferred embodiment of the device showing both electrodes formed  
25 by coating actives directly to the surface of a of non-metallic  
substrate of polymer having a conductor dispersed therein.

5           Figure 3 depicts another preferred embodiment of the disclosed device featuring the actives of the battery mixed directly into the non-metallic polymer substrate also having a conductor dispersed therein.

10           Figure 3a depicts another preferred embodiment featuring the actives of one electrode mixed directly into the polymer substrate and those of the second electrode coated to the surface of the non-metallic substrate.

          Figure 4 depicts a section of particle dispersed conductive plastic.

15           Figure 5 shows a section view of plastic dispersed carbon tape.

          Figure 6 shows a section view of fiber dispersed conductive plastic and carbon tape.

20           Figure 7 depicts a section view of a particle and metallic powder dispersed conductive plastic.

          Figure 8 depicts a view of carbon tape and electrode actives mixed together.

          Figure 9 depicts a cylindrical embodiment of the disclosed device.

25           Figure 10 depicts a prismatic embodiment of the disclosed device featuring a plurality of individual planar stacked

5 electrodes.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

10 Referring now to Figure 1 depicting a side cut away view of a preferred embodiment of the disclosed device 10, the device 10 as assembled forms an electrochemical component or battery and features an assembled cell can 12 formed of a cell casing 14 in sealed engagement with cell cap 16. The sealed engagement of the cell casing 14 with a cell cap 16 is provided through the use of a means for sealed engagement of the cell cap 16 to the cell can 12 which in this case is provided by gasket 18 compressed between the wall of the cell casing 14 and the cell cap 16 and concurrently providing an insulating means between both.

15  
20 Inside the internal cavity defined by the interior dimensions of the cell can 12 is a first current collector 20 adjacent to an attached first electrode 22 thereby forming a unitary structure of current collector 20 and electrode 22. Also, in the interior cavity 19 is a second current collector 24 adjacent to an attached second electrode 26 also forming a unitary structure of second electrode 26 and second current collector 24. Sandwiched between the first electrode 22 and the  
25 second electrode 26 is a separator 28.

5 In this embodiment of the device 10 the first current collector 20 is formed of foil made of one or a combination of copper and aluminum, and has a generally flat upper surface 30 one side which is in contact with the inner surface 32 of the cell cap 16. The shape of the first current collector 20 is  
10 generally dimensioned for maximum contact with the inner surface 32 of the cell cap 16 to maximize the transfer of electrical current communicated to the current collector 20 to the cap 16.

The lower surface 34 of the first current collector 20 is adhered directly to the first electrode 22 which is formed of  
15 actives which are laminated or otherwise coated directly to the lower surface 34 to thereby form a unitary planar structure featuring the first current collector 20 and first electrode 22 which as depicted in figure 1 in the current best mode would be the negative electrode. As depicted the first electrode 22 being  
20 the negative electrode would be formed of actives blended and best suited to performing as the negative electrode. Such active materials currently include one or a combination of active materials from a group consisting of carbon, carbon black, graphite and (MCMB). However those skilled in the art will  
25 realize that other actives might be used in certain circumstances and such is anticipated.

5           The separator 28 is formed of an insulating material such as  
polypropylene that will maintain the desired degree of separation  
between the first electrode 22 and second electrode 26. The  
separator 28 is however sufficiently porous to allow the passage  
of the chosen electrolyte therethrough and between the two  
10 electrodes 26 and 28 as required.

Below the separator 28 and adjacent to the cell casing 16 is  
situated the second current collector 24 which in one preferred  
mode of the device 10 is best formed of either a conducting  
particle-dispersed plastic tape or, a plastic dispersed carbon  
tape having a carbon content of at least 50% by volume. Also  
preferred would be the use of fiber dispersed conductive plastic  
and carbon tape, and particle and metallic powder dispersed  
conductive tape for the second current collector 24. When formed  
from conducting particle-dispersed plastic tape, the plastic is  
continuous phase and sufficient in tensile strength to provide  
the mechanical strength required by the typical continuous  
coating equipment used to adhere the actives thereon which form  
the second electrode 26. Currently used plastic materials  
forming such plastic tape include one or a combination of plastic  
25 materials from a group of plastic materials consisting of  
polystyrene, polyethylene, polypropylene, SBR, or similar plastic

5 materials suited to the purpose.

Dispersed conducting particles bound in the aforementioned plastic forming the tape matrix provide a conducting path for electrical current communicated from the second electrode 26 formed by the active layer adhered to one surface of the second current collector 24. Current preferred conducting particles for inclusion within the particle-dispersed plastic tape include one or a combination of conducting materials from a group of conductive materials consisting of carbon, aluminum, copper, and may be in various forms such as powder, fiber, grains, and other forms suitable to the task.

In the case of plastic dispersed carbon tape, the carbon is the continuous phase and at least 50% by volume and provides not only the required strength during manufacture but also the conducting path for the electrical current. The plastic binder used would be from the aforementioned group of plastic materials. If desired, optionally, metallic powders such as aluminum or copper may be added to either tape matrix to reduce resistance therein.

As noted, two other types of film structures could be used in the formation of the aforementioned plastic tape matrix provide a conducting path for electrical current communicated

5 from the second electrode 26 formed by the active layer adhered  
to one surface of the second current collector 24. These would be  
fiber dispersed conductive plastic and carbon tape and particle  
and metal powder dispersed conductive plastic tape both allowing  
for the desired mix of conductors from a group of conductors  
10 including carbon, aluminum, and copper in different dimensioned  
particles suspended in the tape matrix.

The second electrode 26 which as depicted would in the  
current best mode, function as the positive electrode of the  
battery. It is therefor formed by actives best suited to act as  
15 the positive electrode and which are adhered to the planar  
surface of the second current collector 26 which is to be  
situated adjacent to the separator 28 when the battery is  
assembled. Such actives forming the positive or second electrode  
include one or a combination of actives from a group of actives  
20 consisting of Li, Co, O, Ni, Mn, C, S, and Lithium metal.  
Currently preferred mixtures include,  $\text{LiCoO}_2$ , or  $\text{LiNiCoO}_2$ , or  
 $\text{LiMn}_2\text{O}_4$ . However those skilled in the art will realize that  
other mixtures or components might be used in certain cases and  
such is anticipated. The mixture of actives forming the second  
25 electrode 26 thereby forms a layered but unitary structure with  
maximum contact between the second current collector 24 and the

5 adhered second electrode 26. It is then best dimensioned for maximum contact of one planar side with the interior side of the cell casing 14.

Because both the particle-dispersed plastic tape and the plastic dispersed carbon tape are compressable, yet elastic in nature, they both provide an excellent means to bias the first current collector 20 against the cell cap 16 and concurrently bias the second current collector 24 against the cell casing 14 thereby maximizing surface area contact and increasing current flow from the current collectors 20 and 24 and to the cell cap 16 and cell casing 14 respectively. This is true in all embodiments of the device disclosed herein and an important aspect in increasing efficiency thereof by maintaining maximum contact of the current collectors 22 and 24 with the cell cap 16 and cell casing 14 to maximize current flow and minimize any chance of corrosion therebetween. Further true of all embodiments of the device herein disclosed is that they do not require a charge to keep the battery cell from degrading or corroding after manufacture and therefor can be charged to a charge of 0 to 10 percent of the capacity of the battery cell and then be shipped and stored. This is a major improvement in such battery cells which conventionally require a full charge prior to shipment or

5 risk degradation and corrosion.

Additionally, the flame retardants may optionally be added to the tape matrix of both versions of tape used herein to thereby inhibit fire in the device 10. The retardant materials would be best when of a nature which will not dissolve in the chosen battery electrolyte so that the battery cell chemistry and performance will not be sacrificed under normal conditions. Conventionally used flame retardants are limited in use by their solubility in the electrolyte and should be chosen carefully. Currently, the preferred retardants include one or a combination of retardants from a group of flame retardants consisting of, aluminum tri hydrate, magnesium hydroxide, halogen containing flame retardant like decabromodiphenyl tetradecabromodiphenoxy benzene, lithium carbonate, ethylene bistetrabromophthalimide  $C_{12}OBr_{10}$ , and  $C_{18}O_2Br_4$ . Additionally preferred additives for fire retardance are chemicals that form Carbon Dioxide at high temperatures such as one or a combination of chemicals from a group consisting of  $Li_2CO_3$ ,  $Na_2CO_3$ , and  $CaCO_3$ . However those skilled in the art will recognize that other flame retardants and other chemicals which produce high levels of  $CO_2$  or  $HBr$  or  $H_2O$  could be used or developed for such use and consequently all such substitutions or modifications are anticipated.

5 Still further, since the material forming the second current collector of this embodiment the other embodiments herein disclosed is compressable but elastic, it can be compressed during manufacture without damaging the finished battery yet still providing an outward biasing from inside the battery case to maintain contact pressure between the current collector and the exterior electrical contact.

10 Figure 2 depicts another preferred embodiment of the device in which the first current collector 20 is formed of either a conducting particle-dispersed plastic tape or, or a plastic dispersed carbon tape in the aforementioned fashion in a unitary construction with the first electrode 22 which is formed and adhered to the side of the first electrode 22 adjacent to the separator 28.

15 In this embodiment the second current collector 24 is also formed of either a conducting particle-dispersed conductive plastic tape as represented in figure 4, or, a plastic dispersed carbon tape shown in figure 5 in the aforementioned fashion as a unitary structure with the second electrode 26 which is adhered to the side surface of the second current collector 24 adjacent to the separator 28. This embodiment provides all of the benefits of the aforementioned means to bias the first current collector 20

5 against the cell cap 16 and concurrently bias the second current collector 24 against the cell casing 14 which is provided by the compressable yet elastic nature of both types of tape and can be made fire retardant also by the addition of the aforementioned fire retardant to either tape matrix or to the electrode actives.

10 Another preferred embodiment as depicted in figure 3 depicts an upper electrode 36 and lower electrode 38 distanced by the separator 28. In this embodiment the upper electrode 36 is formed as a unitary structure with the aforementioned actives disbursed in combination with the aforementioned conductives in a solid solution rather than a layered unitary structure. The compression rolling process of making the film with these components creates a low porous electrode. The addition of a good electrolyte absorber such as PVDF provides good ionic conduction and prevents dissolving of the PVDF at high temperatures. A non polar binder  
15 such as PE can be used to provide a binding function and add thermal stability. In the current best mode, the co-polymer PVDF-HFP at 0-15% is used with 5-8% preferred.

20 With the actives interlaced in the tape with the conductives, current is communicated directly by the upper electrode 36 to the cell cap 16 and by the lower electrode 38 to the cell casing 14. The aforementioned elasticity of the material making up both tapes

5 provide a means to bias the upper electrode 34 against the cell  
cap 16 and concurrently bias the lower electrode 38 against the  
surface of the cell casing 14 thus maximizing current flow due to  
the tight contact therebetween and minimizing any corrosion. As  
with the aforementioned embodiments, flame retardant material may  
10 also be added to the mixture making up the solid solution forming  
the upper electrode 36 and lower electrode 38 to impart flame  
retardant characteristics to the assembled device 10.

Figure 3a depicts another preferred embodiment featuring the  
actives of one electrode mixed directly into the polymer substrate  
15 as described above in figure 3 and those of the second electrode  
coated to the surface of the non-metallic substrate also as  
described in detail above as in figure 2.

Figure 8 depicts a view of carbon dispersed plastic tape and  
aforementioned electrode actives mixed together to form an  
20 electrode as a unitary structure.

Figure 9 depicts a cylindrical embodiment of the disclosed  
device 10 wherein the electrodes would both be formed on elongated  
planar film structure in the same fashions and using any of the  
same combinations described above in figures 1 through 3a, only in  
25 an elongated fashion for rolling, while leaving one edge 40 and 42  
of each of the first electrode and second electrode respectively

5     uncoated along an entire edge, if the actives are coated as above,  
to provide a current collector edge for communication of current  
from the elongated electrodes formed in the above referenced  
fashion to and from the electrodes. Any of the above referenced  
film and electrode combinations could be used depending on the end  
10    use of the device and would provide the benefit of fire retardance  
and obviating the need to charge the battery before sale or  
storage.

Figure 10 depicts a prismatic embodiment the device featuring  
stacked electrodes and separators which would be placed inside a  
15    rectangular case and with one edge 40 and 42 of each formed  
electrode uncoated to function as a current collector and to  
communicate electrical current to and from the electrodes. Any of  
the above referenced film and electrode combinations could be used  
depending on the end use of the device and would provide the  
20    benefit of fire retardance and obviating the need to charge the  
battery before sale or storage.

It should be understood that while the best embodiments of  
the device herein disclosed employ all of the group of individual  
improvements herein described and disclosed, greatly improved  
25    performance and utility may be also achieved, using one or more of  
the individual improvements herein disclosed. Further, while the

5 present device and method have been described herein, with  
reference to particular embodiments and components thereof, a  
latitude of modifications, various changes and substitutions are  
intended in the foregoing disclosure, and it will be apparent that  
in some instances some features of the device can and will be  
10 employed to improve conventional battery design and performance  
without a corresponding use of other features without departing  
from the scope of the device and method herein set forth.  
Consequently, all such modifications and variations are included  
within the scope of the invention as defined by the following  
claims.

What is claimed is: